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## Analysis of IoT services, data platforms and re-use of data and solutions in a Smart city context

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**Title:  
Analysis of IoT services, data platforms and re-use of data and solutions  
in a Smart city context**

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**Abstract**

In this paper deployment and operation of IoT services are analysed in a smart city context. A multitude of similar IoT solutions, networks, platforms that often appear as separate closed stovepipes within the same organisation. This often means that it is difficult to re-use systems, knowledge of usage and experiences from procurements within city administrations or within the city. The same obstacles exist when to re-use solutions between cities

Municipalities in Sweden to large extent agree on the need to use interoperable IoT solutions and to avoid stovepipe within the city. However, many new solutions are “closed” and specific for the own unit, and still new stovepipe solutions are deployed.

In this paper we look into the reasons why the stovepipes (still) exist. Results and findings are presented in the following areas

- Stove pipes are still around
- It is not so common with one central IoT platform in the municipality
- Issues with data sharing
- Scalability in the technical domain
- Scalability in the business domain

## 1. Introduction and background of work

The last decade a large number of new smart city services in different areas have been proposed and tested. However, these tests and pilots are often small scale, so potential problems; technical, business related, or organisational, remain to be addressed. In many municipalities and cities there exist a multitude of similar solutions, infrastructures, platforms and providers. The technical solutions often tend to appear as separate stove pipes within the same organisation [1][2][3]. Hence, one challenge for IoT services to take off in the public sector is the multitude of similar solutions, services and platforms that co-exist in the very same city or department. This leads to problems since you cannot re-use systems, knowledge, experience from procurements, and agreements within city administrations or within the city. The same obstacle exist when to re-use solutions between cities. This happens although cities and municipalities have the responsibility to manage the very same type of public services; waste management, home care services, traffic planning and control, parking, etc. Possible reasons may be vendor lock in effects, lack of standardized solutions and data, lack of interoperability.

Hence, a multiple initiatives have been launched to solve these type of problems. International examples are Synchronicity<sup>1</sup> and Open & Agile Smart Cities (OASC)<sup>2</sup>. One stream of efforts address the aspects related to interoperability, standards, open and shared data and data models, platforms etc. These type of challenges are well understood and a lot of research focus on these aspects [3]-[6]. However, even if these technology and data oriented challenges are addressed we can still identify another family of possible showstoppers and challenges, all related to organisation, knowledge and working processes.

Representatives for municipalities in Sweden to large extent agree on the need to procure and deploy interoperable IoT solutions and to avoid stovepipe solutions within the own organisation. However, it turns out that many new solutions are specific for the own department with a low degree of interoperability. There are a lot "new wheels" invented in the public sector and new stovepipe solutions are still created. In this paper we look into the reasons why the stovepipes still exist. The main research question to be addressed are the following:

*What obstacles can be identified for using interoperable and scalable IoT solutions in the public sector?*

*What are the reasons for this development for the case of Sweden?*

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<sup>1</sup> <https://synchronicity-iot.eu/>

<sup>2</sup> <https://oascities.org/>

## 2. Related work

There are several recent overview and literature review papers on IoT solutions in Smart Cities. The papers listed below include descriptions of IoT technology and solutions, applications and challenges.

A survey of IoT technologies, practices and challenges is presented in [1]. A number of weaknesses are discussed including; lack of data control policies, laws for data need to be developed, Interoperability of networks, many and incompatible sensor standards, and the “Myriad of different application frameworks”.

By reviewing the recent research works an overview of IoT technology and applications in life saving, smart cities, agricultural, industrial is presented in [3]. Open areas and challenges are discussed including security and privacy, excess power consumption and, flexibility and interoperability. The large number of IoT devices are also mentioned leading to high costs for servicing and maintenance.

Some overview papers deal with challenges in specific areas related to IoT, e.g.; challenges related to implementation of IoT [7], legal, privacy and cloud security challenges [8], and challenges with the implementation of 5G-IoT due to high data-rates requiring cloud-based platforms and IoT devices based edge computing [9].

Some papers look into the silo aspects and discusses both reasons and possible solutions Development of a greener city infrastructure is discussed in [10]. The traditionally deployed city infrastructure are built to solve only one specific problem e.g. district heating, water supply or waste management, The authors propose broader and cooperating solutions *“the model has now shifted to incorporate multifunctional infrastructure systems that are dependent on each other”*.

The lack of semantic interoperability due to the diversity and heterogeneity in data formats from different source is discussed in [11]. *“The IoT devices provide a great deal of IoT data, mainly used for specific IoT applications....Therefore, existing applications became isolated in vertical silos, each one of them use independently their own model (i.e. ontology), which makes this ontologies also limited to a specific domain. Our approach has the goal of breaking down these vertical silos and achieves a semantic interoperability across IoT domains in cross-domain applications.”*

### 3. Methodology

The results and findings are based on primary data collection performed in two Swedish research projects on smart cities. In the project “City as a Platform” (CaaP) we did study real life smart city applications, use of IoT platforms and data models using “test cases” or Proof of Concepts (PoCs)<sup>3</sup>. The motivation for the project was to support sharing of data within a city and to easily re-use and move data-driven services (including IoT solutions) between cities and municipalities. The project did run 2019 to 2021 with participation of 18 Swedish cities and municipalities including the top three largest cities in Sweden, i.e. Stockholm, Gothenburg and Malmö.

The other project, “Collaborative infrastructure for smart and sustainable smaller municipalities and cities”, did focus on digitalization of public infrastructure in smaller municipalities (“Smart towns”)<sup>4</sup>. The motivation for this project was that problems, challenges and solutions for future smart cities are very much about conditions typical of big cities. In this project, we did target specific conditions and limitations for smaller municipalities. The one-year project did run 2018 to 2019 with five partners; municipalities, local energy companies and one municipality network provider operating in five small municipalities in rural area.

The sets of collected data from the projects are independent and target slightly different aspects of digitalization of the public sector. However, there is a large overlap when it comes to observed challenges and this paper is about these overlapping aspects in the two projects. Participants from the municipalities have contributed with input on service requirements, solutions, experiences and identified problems and challenges. In the CaaP project, work was done with Proof of concepts in seven different application areas [12]:

- Measurement and presentation of bathing water temperature
- Measurement and analysis of traffic flows
- Analysis of pedestrian movement patterns in the city center
- Information about whether a parking loading area is available or not
- Information on the number of available parking spaces in an area
- Alarm if valuable/critical equipment has been moved, examples are lifebuoy, defibrillator and fence at road work
- Reporting on the position and status of equipment, e.g. cleaning machines

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<sup>3</sup> [City as a Platform |](#)

<sup>4</sup> [SAMIR - Collaborative infrastructure for smart and sustainable smaller municipalities and cities — Viable Cities](#)

In the CaaP project, 15 out of 18 project partners have contributed with primary data for this study. Ten of these municipalities have a population between 100 000 and 200 000 inhabitants. The data is collected through the following activities:

- Project work ongoing for at least one year within one or several proof of concepts in different areas
- Feedback from project participants in the end of the project on
  - o The lessons learned from the proof of concepts
  - o The main challenges for municipalities implementing IoT services.
- Workshops on specific topics like IoT architecture, interoperability and classification of information
- Follow-up interviews on digitalization with selected actors within and outside the project: Infraservice in the city of Gothenburg, the local parking company in Borås, home care services in municipality of Karlskrona, the local infrastructure provider in Linköping (Tekniska verken) and, cleaning services unit in Uppsala.

In the project on “smart towns” primary data was collected by a questionnaire and by follow up interviews. In total 20 individuals from 10 municipalities did provide input data. Four municipalities are seen as small with 4000 to 13 000 inhabitants, six municipalities are considered to be medium size (in Sweden) with 40 000 to 112 000 inhabitants.

The questions in the questionnaire and at the interviews were grouped as follows:

About the current situation and existing plans

- What types of networks have digital functions for operation and monitoring
  - and not?
- What physical infrastructure networks should be expanded with digital functions?

About potential benefits, problems and obstacles

- What problems do you have today with different types of infrastructure?
- What types of problems do you think can be solved with the help of digitization?
- What obstacles can you see to implement digitization?

About collaboration within and between (small) municipalities

- What kind of collaboration and coordination to you have currently?
- What opportunities can you identify for collaboration within the municipality?
- What opportunities can you identify for collaboration between municipalities?

#### **4. Summary of findings from project on digital infrastructure in small municipalities**

##### **Current situation and existing plans**

Digital functions for operation and monitoring are currently represented in a variety of systems: fiber/city network, electricity network, district heating, water supply.

Some examples where digital functions are missing: monitoring of passive parts of fiber networks, low-voltage networks, drinking water and, waste and storm water systems.

Examples of planned expansion are: remotely controlled functions in the electricity networks, remote reading of water meters, radio based IoT network.

##### **Benefits, problems and obstacles**

Reported problems with today's systems and infrastructure include:

- Aging district heating and water & sewage systems, typically they may lack monitoring and/or have large losses
- Lack of ability to deal with climate change, extreme weather or threats
- Diversity of different systems and types of systems
- Lack of integration between the local systems

These aspects are listed as challenges and possible obstacles to digitization

- “Money”, financial resources in small municipalities
- Knowledge and IT competence within the municipality
- Difficult to get management attention for use of new technology
- Difficult to get a mandate to bring about change and to change working methods
- Too strong dependence on suppliers and/or lock in to certain supplier

##### **Collaboration and coordination within and between municipalities**

The answers on the current situation for collaboration and coordination says that it is common with collaboration between municipality and local municipal companies, typically the local energy company bit low level of collaboration between "other" companies and the municipality.

Opportunities for collaboration within the municipality has been identified for communication and technology platforms and for forming a joint operating organization. Development of a common strategies and procurement are seen as promising areas for collaboration between municipalities. There are doubts about joint operating organization for multiple municipalities, mentioned reasons are differences between specific areas, and that the organisation need to have a local presence.

##### **Summary**

The results of survey responses and discussions within the project on digitalization in small municipalities indicate that the reported obstacles and challenges for digitization are not primarily technical but mostly depend on organization and tradition.

## 5. Findings from the City as a Platform project

### Overall

In this section, observations of different types of challenges are presented:

- Stove pipe solutions are still around
- Difficulties to share data
- Scalability in the technical domain
- Scalability in the business domain

### Stove pipes

Here we start with some examples, the first one is about procurement of a data platform for alarm for home care services. It is intended for home care services only, no other alarms or other type of data s planned as input to this platform.

One reason for developing an “own” solution is that there is no central IoT platform in the municipality for storing and sharing data. One example is when a department deploy sensors to monitor the own physical infrastructure. The collected data goes directly from the sensor to the system at user department, and there is no sharing of data or using any other city communication or IoT infrastructure to transfer data.

Data can also be collected and stored by some ICT infrastructure provider, and directly send to the user. This infrastructure provider can typically be the local energy company, the municipality network provider or a general provider of physical infrastructure, e.g. water or district heating, see figure 1.

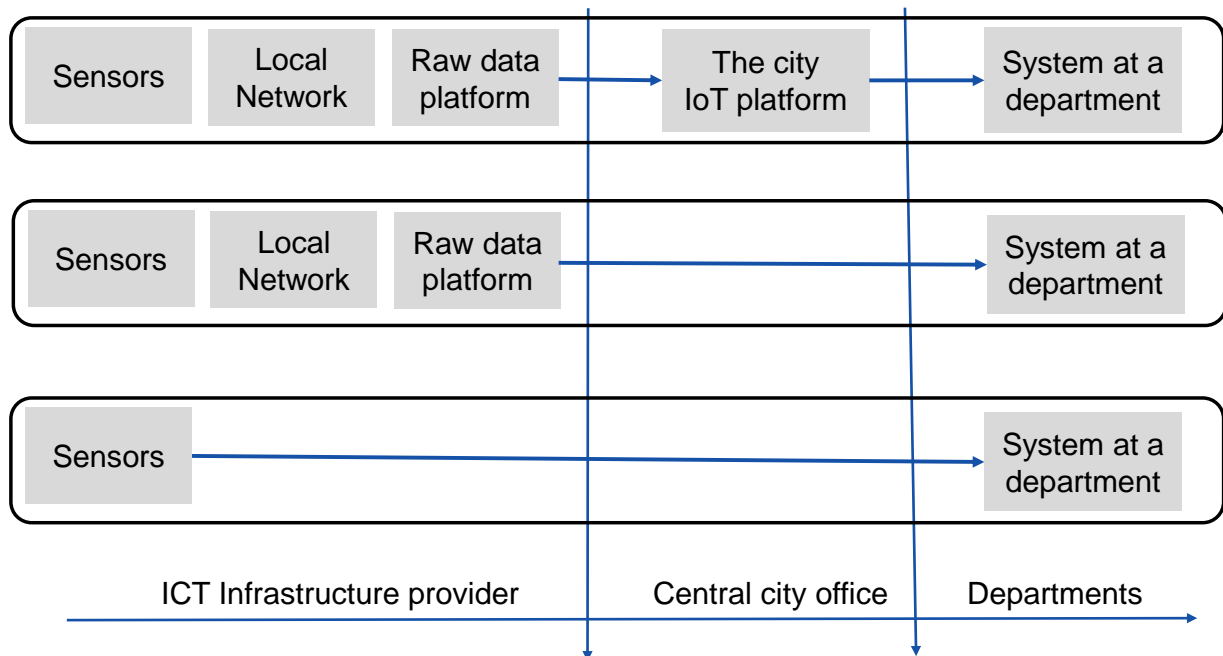


Figure 1. Examples of IoT architectures and data flow between different nodes.



## **To share data**

Measurement and presentation of local bathing temperatures is a popular test case for use of IoT. It includes the whole chain; measurement at sensors, data transfer, data storage and presentation. The FIWARE data model for "Water quality" can be used where temperature is one data element.

There is no common sharing of data between municipalities; it may not be needed because the data is of local interest. However, municipalities can contribute with data to the national map of bathing sites called EU baths provided by the Swedish Marine and Water Administration.

For a municipality to be able to contribute, it is not enough to report only temperature, you also need to measure and report bacterial content (s), the presence of algal blooms and to state general information about the bathing area itself. Note that in FIWARE there is an applicable data model called "Water Quality Observed", where the temperature is one of the parameters. However, if the municipality cannot report the actual "water quality" (bacterial content, algal blooms), it is not qualified to participate as an EU bathing site.

## **Scalability in the technical domain**

A Swedish city experienced challenges when trying to configure and connect IoT devices using solutions provided by a mobile operator. There are tools to manage connectivity where mobile operators see this as a part of their offer but they do not necessarily see device management as part of their offer.

Use of physical SIM cards can create problems and built-in obstacles when large number of devices need to have the correct SIM card installed. This creates a logistical challenge when upscaling.

All devices need to be configured with the correct SIM card and the card's associated ip-address, username and password. As the mobile operators supply tools to administer the SIM cards (connectivity management) but not the administration of the devices (device management) a tool is required to scale up. This tool for management of devices needs to include the capability to handle error codes from the device, firmware updates etc.

The municipality says that the device management and data management need to be separated where Device/Connectivity management should be part of the IoT platform and Data/Information Management is a part of the Data Platform.

## Scalability in the business domain

Tests with different types of actors may work with a limited number of actors but put into a real life situation with many actors of the same type. Small-scale tests with just one actor of each type in a value network may hide the complexity in the business domain. When scaling up to municipality as the main customer need to have business agreements with many actors of the same type, actors that are competitors,

One example is the installation and use of smart locks for home care. In the pilot phase, there was one actor for each type. Besides the municipality, there were one lock provider, one home care service provider and one real-estate company. Still there were problems to agree where to put support system for managing locks and access rights. Both the home care provider and the real-estate company both had the resources and wanted to take care of it. Big companies with national presence may not want to lose control and let someone else manage or get information from the own business support systems. In this case it was not an option that the municipality should enter as a neutral actors and manage the access rights.

When scaling up and implementing this kind of services in real life, this type of problem becomes very large when more actors need to be part of the service. In a large municipality it may be 10-20 home care providers and there is a large number of real-estate companies. Hence, small-scale tests with just one actor of each type in a value network may hide the complexity in the business domain. The municipality as the main customer need to have business agreements with many actors of the same type, actors that also are competitors.

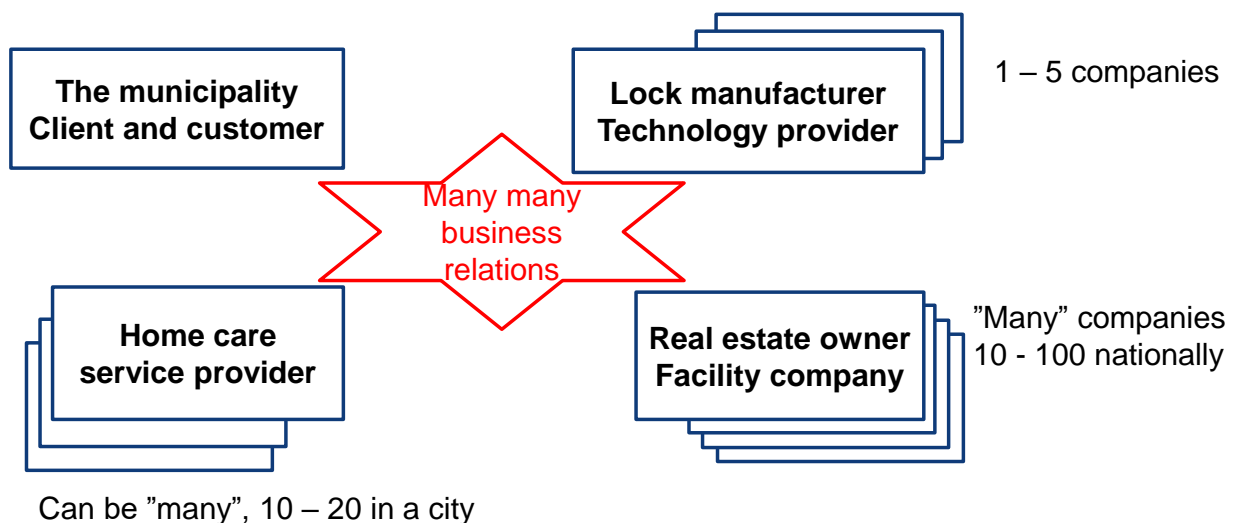


Figure 2. Ecosystem for the case Smart locks for home care services. Multiple companies for each type of actor implies many business relations

## 6. Discussion and conclusions

In general there is a lot of insights on the fragmentation of IoT services and many stove pipe solutions. Largely the municipalities agree on the need to use interoperable IoT solutions and to avoid stovepipe within the city. However, many new solutions are specific for the own unit and, hence, new stovepipe solutions are deployed.

Municipalities in general agree on a framework with common data models and APIs and the use of a “central” IoT data platform, Figure 3. However, it turns out that many pilots and IoT services are deployed as separate and stand-alone solutions, see right hand side of figure 3. The separate service has its own set of sensors, communication infrastructure and data handling.

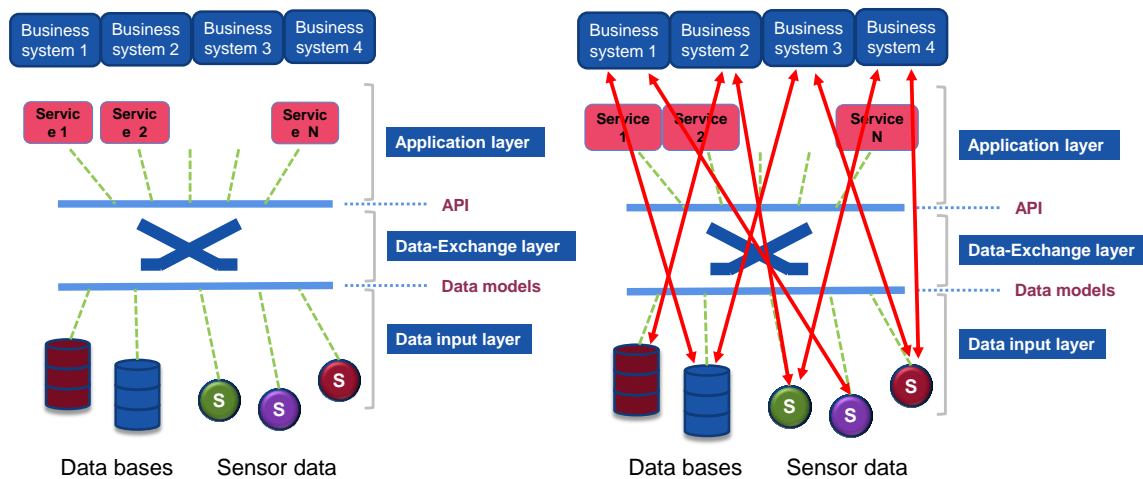


Figure 3. Proposed framework for management of IoT data , to the left

As an option you have the specific solution (red arrows), to the right

One reason can be that it is not so common with a technical architecture with a central IoT platform. Another reason can be that municipalities run many different businesses, operated by different departments with different “business models”. Hence, it may be that each department focus on the own business. It may also be that there are no clear incentives or benefits to share data.

Another aspect, mentioned at interviews, is that providers often offer specific and tailor-made solutions. Technology providers and consultancy companies offer IoT platforms, data sharing features, integration, etc., to different departments. The same system is then delivered multiple times and hence silos are established or maintained.

Another finding is that many real life aspects are not (fully) seen in pilot projects, they become evident when you scale up. Examples are provided both for operation and management and for business aspects including a multitude of actors.

You can compare IoT infrastructure and services with other sectors with large ICT infrastructure, e.g. mobile communications, financial institutions, energy. Key differences are:

- Specific actors provide the service, e.g. mobile operators and payment providers, i.e. you are not your own service provider as many municipalities are
- For each sector there are a few big actors in each country
- There exist agreed standards and clear interfaces, e.g. 3GPP for mobile networks

For the future, one possible scenario is that you go on with the traditional approach;

- "Single - functional infrastructure deployed and operated by municipalities"

Other scenarios can be

- ICT infrastructures provided by external "operators"
- Multi-functional infrastructures deployed and operated by municipalities

The last option is proposed in the recent papers by Kaluarachchi [10] and Jurva et al [13] .

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